

*AN INVESTIGATION OF PEAK SHIFT AND  
BEHAVIORAL CONTRAST FOR AUTOSHAPED  
AND OPERANT BEHAVIOR*

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Instrumental treadle press and nonreinforced key peck responses were monitored during discrimination training and generalization testing in pigeons on positive and negative reinforcement schedules. In Experiment 1, six pigeons pressed a treadle for food on a multiple variable-interval extinction schedule. In Experiment 2, three pigeons pressed a treadle to avoid shock on a multiple free-operant avoidance extinction schedule. Different color keylights signaled the S+ and S- components. Some positive behavioral contrast occurred during discrimination training, but the effect was small. Pecking occurred to the S+ keylight in Experiment 1 but not in Experiment 2. On stimulus generalization tests, all subjects displayed a positive peak shift when pressing the treadle for food or to avoid shock. However, peak shift was *not* found for nonreinforced "autopecks" on the stimulus key, although an area shift was observed in Experiment 1. This is the first demonstration of peak shift for pigeons pressing treadles and the only reliable demonstration of peak shift when negative reinforcement maintained responding. These results, in combination with previous demonstrations of peak shift for rats pressing levers and pigeons pecking keys, indicate that peak shift is a general by-product of operant discrimination learning, since it occurs across a variety of the organisms, responses, and reinforcers.

*Key words:* behavioral contrast, peak shift, stimulus generalization, autoshaping, treadle pressing, pigeons

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Multiple schedule discrimination training often results in certain interactions or "by-products" (Terrace, 1972). One such by-product is positive behavioral contrast, i.e., an increase in responding in an unchanged component of a multiple schedule when responding decreases in another changed component. Positive behavioral contrast has been observed for pigeons pecking keys (Bloomfield, 1967; Terrace, 1966a; Reynolds, 1961a) and rats pressing levers (Gutman, 1977; Gutman, Stutterer, & Brush, 1975). However, when pigeons press treadles, positive behavioral con-

trast has *not* been observed (Hemmes, 1973; Scull & Westbrook, 1973; Westbrook, 1973).

One factor that may contribute to behavioral contrast in the key pecking situation is the addition of elicited "autopecks" during differential reinforcement conditions to the operant pecks normally occurring during non-differential conditions (Gamzu & Schwartz, 1973). This "additivity" explanation of behavioral contrast applies only when the response required of the organism is related to its natural consummatory response (e.g., pigeons pecking for food). Hemmes (1973) proposed that the failure to obtain behavioral contrast when pigeons press treadles is due to the absence of this elicited consummatory-like behavior. Nevertheless, since behavioral contrast is seen when rats press levers—a situation in which the response has no apparent relationship to the consummatory response of the organism—Hemmes' explanation seems inadequate. It is possible that stimulus parameters were not optimal for the production of positive behavioral contrast in those situations where pigeons pressed treadles. Malone (1975) and Kodera and Rilling (1976) demonstrated that

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the likelihood of contrast increases with more similar discriminative stimuli. In the studies that failed to obtain positive contrast using pigeons treadle pressing, the discriminative stimuli differed on several dimensions.

The present experiment studied behavioral contrast using treadle pressing and food reinforcement, with stimulus parameters chosen to optimize the occurrence of contrast. In the present study the discriminative stimuli were very similar. They differed predominantly in hue, one being a 572-nm light and the other a 580-nm light. These stimuli were chosen because there is little change in the pigeon photopic spectral sensitivity function between 572 and 580 nm (Blough, 1957; Yager & Romeskie, 1975). Also, there is only a small variation in control by saturation between these stimulus values (Blough, 1975).

To make the occurrence of behavioral contrast even more likely, a response-reset dependency was used to reduce responding in the Extinction component (S-). With this dependency in effect, responses in S- served to prolong the extinction component. Some data indicate that the response-reset dependency may enhance behavioral contrast. Farthing (1975) found behavioral contrast with pigeons key pecking when he used auditory stimuli and a response-reset dependency, while Schwartz (1974) failed to obtain contrast under similar circumstances without the response-reset procedure.

An additional by-product of multiple schedule discrimination training is generalization peak shift. If a stimulus generalization test is given following intradimensional discrimination training, the peak of the gradient frequently does not occur at the positive discrimination stimulus (S+), but at a stimulus displaced from S+ in a direction away from the negative stimulus (S-) (Hanson, 1959). Although most studies showing peak shift have involved key pecking in pigeons, the phenomenon has been demonstrated reliably in rats and guinea pigs using auditory discriminations and lever pressing (Pierrel & Sherman, 1960; Thomas & Seltzer, 1972; Weiss & Schindler, 1978). However, peak shift has not been demonstrated in pigeons with a response other than key pecking.

Experiment 1 of the present study examined the shapes of stimulus generalization gradients following discrimination training for

operant treadle pressing in pigeons. Since peak shift has been observed with various organisms, stimuli, and responses, one would expect to find peak shift when pigeons press treadles. Nevertheless, because of the unique relationship between pecking and food, phenomena observed when pigeons peck keys are not always forthcoming with other responses (see Schwartz & Gamzu, 1977).

#### *Nonreinforced Pecks*

When one of two alternating stimuli signals food while the other signals no food, pigeons come to peck the stimulus independent of the consequences of pecking (Gamzu & Schwartz, 1973). During the present discrimination training the S+ and S- stimuli were located on a stimulus key situated on the chamber wall above the treadle. This provided an opportunity to record stimulus-directed nonreinforced key pecks (autopecks). Concurrent but separate emission of operant key pecks and stimulus-directed autopecks during multiple-schedule discrimination training has been observed with separate stimulus and response keys (Keller, 1974; Schwartz, 1975; Schwartz, Hamilton, & Silberberg, 1975). However, the present investigation is the first study of stimulus-directed nonreinforced pecking during discrimination training using an operant response which differs from the consummatory behavior of the organism.

Finally, Experiment 1 determined the shape of generalization gradients for stimulus-directed autopecks following intradimensional stimulus discrimination training. Demonstrations of excitatory and inhibitory autopeck gradients following interdimensional training (Tomie, Davitt, & Engberg, 1976; Wessells, 1973) suggest that peak shift will occur with autopecks following intradimensional training (Blough, 1975; Spence, 1937). However, autopeck gradients following intradimensional discrimination training have not been reported previously.

In summary, instrumental treadle-press and autoshaped key-peck responses were monitored during discrimination and generalization testing in pigeons on positive reinforcement schedules where stimulus parameters and training contingencies presumably were arranged to optimize the occurrence of behavioral contrast and peak shift.

## EXPERIMENT 1A

## METHOD

*Subjects*

Three male White Carneaux pigeons, approximately one year old at the beginning of the experiment, served. They were maintained at 80% of their freefeeding weights. All were experimentally naive and were housed separately with free access to water and grit.

*Apparatus*

An operant conditioning chamber measuring 32.5 cm high by 29.5 cm long by 23 cm wide was used. The chamber was a stainless steel box containing a foot treadle 5-cm long by 5-cm wide. The treadle, located on the front wall, was 4 cm from the left wall, 14 cm from the right wall, and 3 cm from the floor. A force of .6 N at the center of the treadle and a downward displacement of 1 cm were required to operate a microswitch connected to the treadle. Centered 18 cm above the treadle was a 2-cm diameter stimulus key. The stimulus key was operated by a force of .15 N. A food magazine 6 cm wide and 6 cm high was located 13 cm from the left wall, 4 cm from the right wall, and 4 cm from the floor. The chamber was enclosed in a sound-attenuating chest with an exhaust fan mounted in the ceiling. This fan also served to mask extraneous noise. Electromechanical equipment, located in an adjacent room, arranged the schedule contingencies and stimulus presentations. Data were recorded on digital counters and were also monitored on a cumulative recorder.

The visual stimuli projected on the stimulus key were generated by Dectric Optics 2-cavity interference filters with 5-nm bandpass and both ultraviolet and infrared blocking. Peak transmission of the filters were at 540, 552, 558, 567, 572, 575, 580, 588, 598, and 611 nm. The illumination source was a GE 18-amp T10/2p6v microscope illuminator bulb with ribbon filament and an output of 1800 lumens. The spectral emission between 540 and 610 nm was best fit by a black body radiator with a color temperature of 2850° K. The spectral energy distribution in this wavelength interval has a radiometric range of .2 log units (Wysocki & Stiles, 1969, p. 20). The collimated monochromatic light transilluminated the translucent stimulus key. The lamp source was 50

cm from the key. Each of the 10 filters could be placed in the path of the light beam by activating the appropriate solenoid.

*Procedure*

*Initial training.* On Days 1 and 2, the three subjects were magazine trained and trained to press a treadle to obtain access to mixed grain. For subjects 1 and 3, this was done in the presence of a 572-nm light; for Subject 2, in the presence of a 580-nm light. Each subject then received continuous reinforcement (CRF) training for one session, in which every treadle press was reinforced with a 4-sec access to grain. On Day 4, food was delivered on a variable-interval (VI) 15-sec schedule in which the first treadle press occurring at a specified but variable time after the last reinforced response produced access to grain, with a mean interval of 15 sec. A multiple VI 15-sec VI 15-sec schedule was initiated for Days 5 and 6. Responses were reinforced on a VI 15-sec schedule, with stimuli of 572 nm and 580 nm. A stimulus was presented for a 45-sec period, followed by a 1-sec blackout during which no light was present in the chamber. After each blackout, the probability was .5 that 572 nm was initiated and .5 that 580 nm was initiated. This stimulus-presentation procedure resulted in a random sequence of stimuli. On Day 7, the mean VI value was increased to 30 sec so that the schedule became multiple VI 30-sec VI 30-sec. Each subject was trained until there was no systematic trend in response rates over four consecutive sessions during either stimulus condition. Subjects 1, 2, and 3 spent 13, 8, and 5 days on the multiple VI 30-sec VI 30-sec schedule. Sessions lasted until 60 reinforcements were delivered.

*Discrimination training.* When response rates in S1 and S2 were stable, the schedule was changed to multiple VI 30-sec Extinction. The VI-associated stimulus (S1) was 572 nm for Subjects 1 and 3 and 580 nm for Subject 2. The other stimulus was present during Extinction (S2). Stimulus presentations remained the same as during multiple VI 30-sec VI 30-sec training. A response-reset dependency was initiated after 8, 14, and 12 sessions of discrimination training for Subjects 1, 2, and 3, respectively. Under this dependency during S2, the extinction-associated stimulus, responses on the treadle reset the component timer. Consequently, the pigeon had to cease responding

for at least 45 sec in order for S1 to be initiated. As during nondifferential training, sessions lasted until 60 reinforcements were received. When the response-reset procedure was in effect, S2 response rates were computed using the total time S2 was lighted as the time base.

Subjects were trained on the final baseline schedule until they had met the following criteria for four consecutive days: (1) The S2 (Extinction) response rate was no more than 25% of the S1 (VI) response rate; (2) there was abrupt and sustained response rate *reduction* on at least 75% of S2 presentations that followed S1 presentations; (3) there was an abrupt and sustained response rate *increase* on at least 75% of the S1 presentations that followed S2 presentations; (4) no increasing or decreasing trend in response rate was noted in either component. Subjects 1, 2, and 3 received 27, 26, and 19 sessions, respectively, on the terminal schedule. During all stages of training, pecks on the stimulus key were recorded but had no scheduled consequences.

*Extinction stimulus-generalization test.* This test was administered when the discrimination criteria were met. On the day of the test, the usual reinforcement dependencies were in effect for approximately 15 min. Then 12 randomized blocks of 10 stimuli were presented. Each block consisted of 45-sec presentations of 540-, 552-, 558-, 567-, 572-, 575-, 580-, 588-, 598-, and 611-nm stimuli. The order was randomized within each block of 10 stimuli, and a 1-sec blackout intervened between successive stimulus presentations. Reinforcement was discontinued during testing, and the complete test was administered within one session. As during training, pecks on the stimulus key were recorded but had no scheduled consequences.

## RESULTS

### Training

Figure 1 shows treadle pressing rates of Subjects 1, 2, and 3 during the last five sessions of multiple VI 30-sec VI 30-sec training, multiple VI 30-sec Extinction training, and multiple VI 30-sec (Extinction + response-reset) training. During nondifferential training, each animal produced comparable treadle pressing rates in S1 (closed circles) and S2 (open circles). When multiple VI 30-sec Extinction training began, response rates in S2 decreased for

Subjects 1 and 3 but not for Subject 2. Treadle pressing rate increased in S1 substantially for Subject 2 and slightly for Subject 1. When the response-reset contingency was imposed, S2 response rates decreased and S1 response rates increased for all subjects.

Key pecking rates for Subjects 1, 2, and 3 are shown in Figure 2. Little or no key pecking occurred during multiple VI 30-sec VI 30-sec training. Each subject began pecking during multiple VI 30-sec Extinction training, with additional increases in key peck rates upon imposition of the treadle response-reset contingency in S2. Subject 1 initially produced higher key pecking rates in S2 than in S1, but as the treadle pressing discrimination improved, key peck rates became consistently higher in S1 than in S2. Subject 3 produced elevated S2 key peck rates during several sessions of discrimination training, but eventually, S1 key peck rates became consistently higher than S2 key peck rates. Subject 2 did not begin key pecking until the eleventh day of discrimination training, and key peck rates were always higher in S1 than in S2.

### Extinction Stimulus-generalization Test

Figure 3 shows total treadle presses (closed circles) and key peck (open circles) during the extinction generalization test. For every subject, the peak of the treadle press gradient was shifted from S+ in a direction away from S-. The peak of the key peck gradient occurred at 575 nm, the stimulus intermediate to the S+ and S- stimuli, for Subjects 1 and 3. The peak occurred at S+ (580 nm) for Subject 2. Although peak shift was not observed for key pecking, an "area shift" (Terrace, 1964) is present, in that the key pecking gradients are asymmetrical around the peak, with substantially more than 50% of the area under the curve being on the side away from S-.

## EXPERIMENT 1B

In Experiment 1A, pigeons were reinforced for treadle pressing on a multiple VI VI schedule and then on a multiple VI Extinction schedule. Since the chamber was arranged so that key pecks and treadle presses could occur simultaneously, it is possible that a key peck could be immediately followed by food presentation, thereby producing superstitious operant key pecking (Boren, 1969). This key

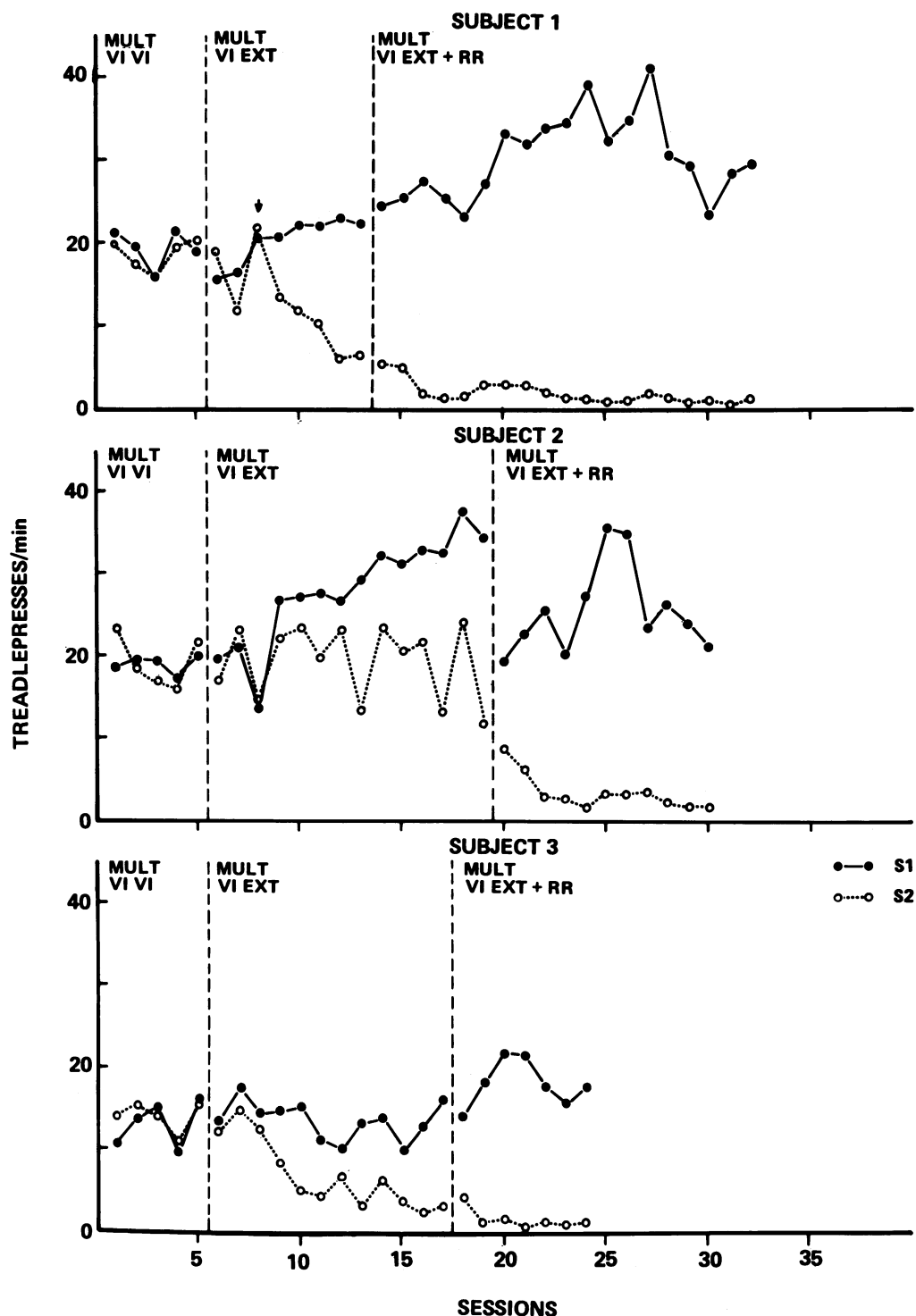


Fig. 1. Treadle-pressing rates (treadle presses/min) for each subject in Experiment 1A during nondifferential training, multiple VI 30-sec VI 30-sec, and differential training, multiple VI 30-sec Extinction and multiple VI (Extinction + response reset). Closed circles show rates during the S1 component, and open circles show rates during the S2 component. The arrow points out a session during which programming equipment failed, so that the pigeon was reinforced in both schedule components.

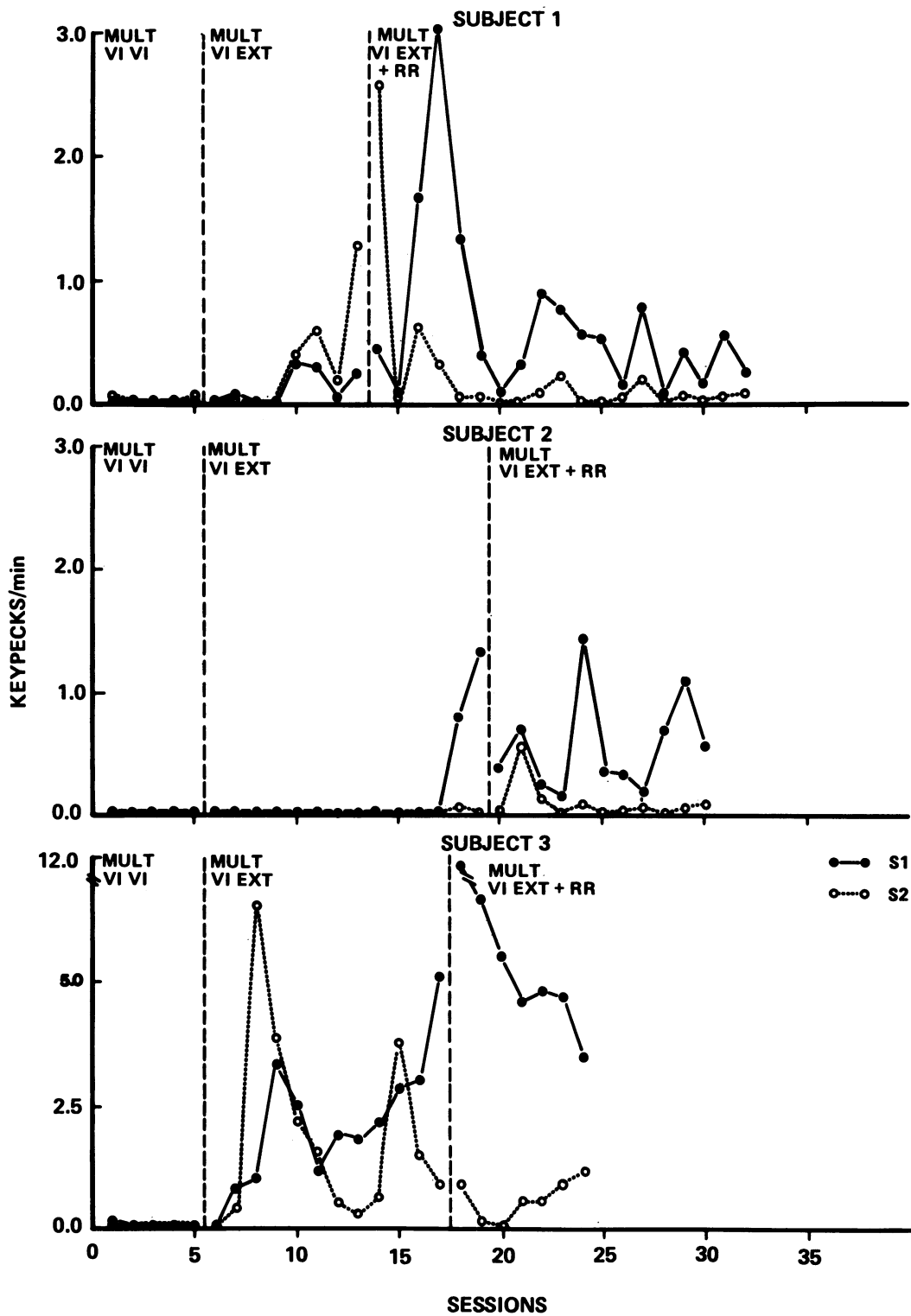


Fig. 2. Key-pecking rates (key pecks/min) for each Experiment 1A subject during each stage of treadle press training. Closed circles represent key pecks in the S1 component; open circles represent key pecks in the S2 component. Key pecking had no consequences in either component.

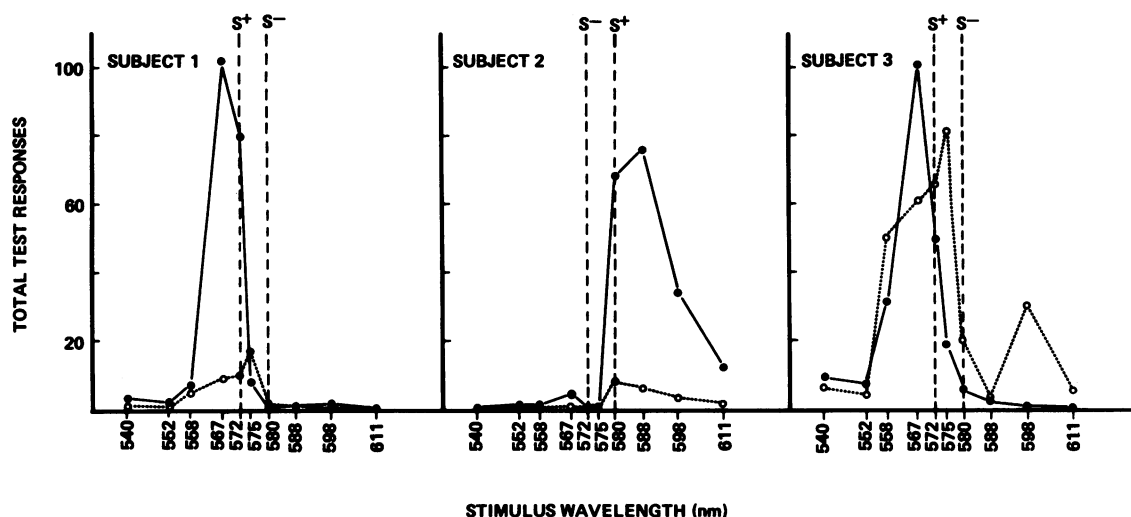


Fig. 3. Total treadle presses (closed circles) and key pecks (open circles) emitted to each stimulus during the extinction stimulus-generalization test for each subject in Experiment 1A.

pecking would be indistinguishable from autopecks. In Experiment 1B, procedures were used to determine if the stimulus-directed key pecks were superstitious operant key pecks. Pigeons in Experiment 1B received training similar to that in Experiment 1A, except that the experimental sequence involved three stages: (1) multiple VI Extinction, (2) multiple VI VI, and (3) multiple VI Extinction. Gamzu and Schwartz (1973) found that with this sequence autopecks emerge during the Stage 1 differential training, disappear during Stage 2 nondifferential training, and reappear during Stage 3 differential training. In contrast, superstitious pecks could emerge at any time and should have a higher probability of occurrence during the nondifferential (multiple VI VI) training because of the greater frequency of food presentation.

Schwartz, Hamilton, and Silberberg (1975) found that nonreinforced pecks on the stimulus key (autopecks) occurred primarily just after a change in stimulus to the S+ for food, while pecks on the separate response key (operant pecks) did not show this temporal patterning. In order to analyze further the nature of key pecks in Experiment 1, the present study determined the percentage of pecks occurring in the first 10 sec of each S+ component.

#### METHOD

##### Subjects

Three male White Carneaux pigeons, approximately one year old at the beginning

of the experiment, served as subjects. They were maintained at 80% of their freefeeding weights. All were experimentally naive and were housed separately with free access to water and grit.

##### Apparatus

The apparatus was the same as that in Experiment 1A.

##### Procedure

*Initial training.* As in Experiment 1A, three pigeons (Subjects 4, 5, and 6) received magazine training, training to press a treadle for access to mixed grain, CRF training, and VI 15-sec training on Days 1, 2, 3, and 4, respectively. Initial training took place in the presence of a 572-nm light for Subject 5 and 580-nm light for Subjects 4 and 6. Then the procedure diverged from that of Experiment 1A. VI 15-sec training continued for one additional day, followed by discrimination training on Day 6.

*Discrimination training.* On Day 6, a multiple VI 15-sec Extinction schedule was initiated. The VI-associated keylight (S1) was 572 nm for Subject 5 and 580 nm for Subjects 4 and 6, while the Extinction-associated keylight was 580 nm for Subject 5 and 572 nm for Subjects 4 and 6. As in Experiment 1A, a stimulus was presented for 45 sec, followed by a 1-sec blackout. After each blackout the probability was .5 that the 572-nm light was initiated and .5 that the 580-nm light was initiated. Training on this schedule continued

until 75% of the treadle presses occurred in S1. Subjects 4, 5, and 6 received 35, 16, and 30 days, respectively, of multiple VI 15-sec Extinction training. Finally, the schedule was changed to multiple VI 30-sec Extinction, and the response-reset dependency in S2 was initiated after 4, 4, and 3 sessions for Subjects 4, 5, and 6, respectively.

Subjects were trained on multiple VI 30-sec Extinction until they met the discrimination criteria set forth in Experiment 1A, with the provision that each pigeon received at least 10 days of multiple VI 30-sec Extinction training. Subjects 4, 5, and 6 received 20, 15, and 10 days, respectively, of this multiple VI 30-sec Extinction training. During the last five days of multiple VI 30-sec Extinction training for Subject 5, C2 components were lengthened from 1 min to 3 min. This was done because Subject 5 failed to peck the key during discrimination training. Since autopecking increases in frequency when S- is lengthened relative to S+ (Terrace, Gibbon, Farrell, & Baldock, 1975), it was thought that this procedure would increase the probability of key-peck occurrence. During all stages of training, pecks on the stimulus key were recorded but had no scheduled consequences. Sessions terminated after 60 reinforcements.

*Extinction stimulus-generalization test.* A stimulus generalization test, identical to that in Experiment 1A, was administered, when the discrimination criteria were met. Treadle presses and key pecks were recorded.

*Nondifferential training.* Multiple VI 30-sec VI 30-sec training, with the 572-nm and 580-nm keylights in S1 and S2, was begun on the day following the generalization test. Training continued for at least 10 sessions and until the following criteria were met: (1) No increasing or decreasing trend in treadle press rate across sessions in either S1 or S2 was noted for four consecutive days; (2) no increasing or decreasing trend in keypeck rate across sessions was observed in either S1 or S2 for four consecutive days. Subjects 4 and 5 received 10 days, and Subject 6 received 15 days of nondifferential VI training.

*Second differential training.* Immediately following nondifferential training, the multiple VI 30-sec Extinction schedule was reinstated. Training on this schedule continued for at least 10 days and until discrimination criteria of Experiment 1A were met.

*Second extinction stimulus-generalization test.* When discrimination criteria were met, a second stimulus generalization test was administered. This was identical to the previous tests except that 6 instead of 12 randomized blocks of 10 stimuli were presented. The test was shortened in this manner because it was observed that responding extinguished more rapidly on the second test than on the first. Data obtained in the first 6 blocks of the 12-block tests did not differ qualitatively from total test data; i.e., generalization gradients generated from the first 6 blocks revealed the same characteristics as gradients generated from the total 12-block tests. Consequently, comparison of the 6-block and 12-block tests is valid.

## RESULTS

### Training

Treadle press rates of Subjects 4, 5, and 6 decreased in the Extinction component as rates increased in the VI component. During VI VI training, S1 and S2 rates became approximately equal. Since these subjects began discrimination training before their S+ response rates were stable, multiple-schedule interactions cannot be evaluated.

Key pecking rates for Subjects 4, 5, and 6 in S1 (closed circles) and S2 (open circles) are shown in Figure 4. Before nondifferential training, all subjects were key pecking, with higher rates in the S1 component than in S2. During multiple VI VI training, key pecking virtually ceased. When multiple VI 30-sec Extinction contingencies were again initiated, key pecking rapidly increased.

As shown in Table 1, more key pecks were found in the first 10 sec of S+ than expected if pecks had been uniformly distributed throughout the interval. For Subjects 4 and 6 more pecks were observed than expected in the first 10 sec during every multiple VI Extinction training session. Subject 5, which had very low absolute key peck rates, produced more pecks in the first 10 sec than expected by chance in 9 of 15 sessions.

### Stimulus-Generalization Test

Total responses during the first stimulus-generalization test for Subjects 4, 5, and 6 are shown in Figure 5. Treadle presses are represented by closed circles and key pecks by open circles. Each subject produced a peak fre-



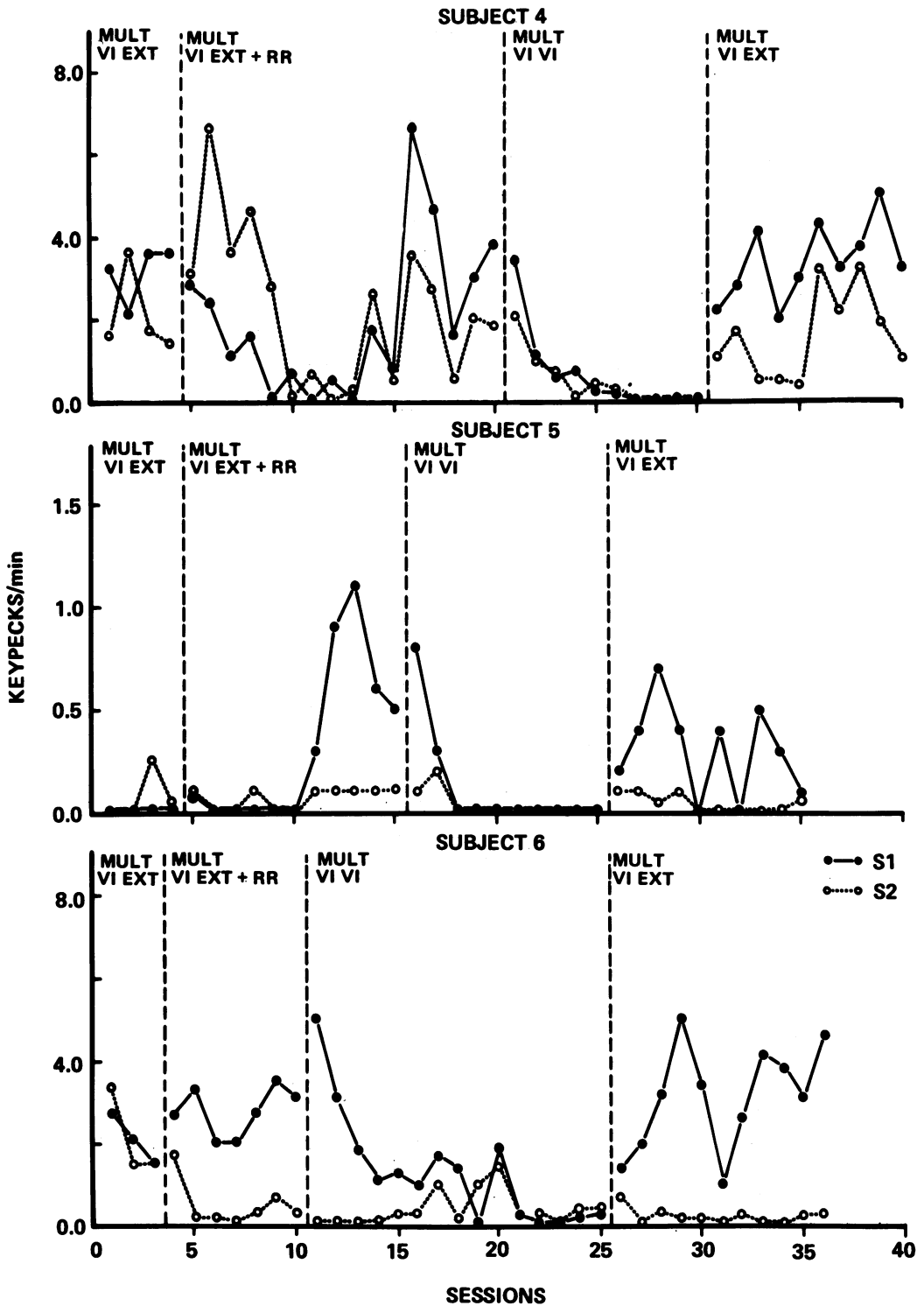


Fig. 4. Key-pecking rates (key pecks/min) for Experiment 1B subjects during each stage of treadle-press training. Closed circles represent key pecks in the S1 component; open circles represent key pecks in the S2 component. Key pecks had no consequence in either component.

Table 1  
Percent of total S+ keypecks expected (*E*) and observed (*O*) in first 10 sec of a component.

Subject	Session	Mult VI Ext		Mult VI VI		Mult VI Ext	
		<i>E</i>	<i>O</i>	<i>E</i>	<i>O</i>	<i>E</i>	<i>O</i>
4	1	15.6	73.8	12.3	62.3	7.8	71.4
	2	9.6	63.0	7.0	38.5	10.3	58.9
	3	11.5	51.4	4.0	25.0	10.4	41.0
	4	10.0	46.2	7.9	71.4	12.4	58.3
	5	11.4	45.5	10.6	100*	10.5	61.3
	6			11.8	100*	9.0	40.8
	7			0	0*	9.0	68.8
	8			0	0*	9.0	39.0
	9			0	0*	11.7	49.6
	10			11.2	0*	11.8	48.0
5	1	10.3	0	7.9	25.0*	10.3	100
	2	11.4	10.0	3.9	20.0	10.0	40.0
	3	7.4	13.9	0	0*	11.3	35.7
	4	10.8	40.0	0	0*	11.4	0
	5	11.3	41.7	0	0*	14.0	0*
	6			0	0*	13.8	44.4
	7			0	0*	0	0*
	8			0	0*	6.6	8.3
	9			0	0*	9.4	0*
	10			0	0*	9.2	33.3*
6	1	11.1	50.0	15.9	50.0	7.2	61.1
	2	10.6	59.1	6.6	17.5	10.4	65.3
	3	9.0	36.7	10.2	28.6	16.0	48.7
	4	12.1	50.0	10.2	25.0	13.4	56.4
	5	7.6	64.0	10.3	53.8	12.1	38.4
	6	9.1	43.2	12.0	18.2	12.3	41.7
	7			4.1	25.0	7.2	23.1
	8			5.3	27.8	16.3	42.6
	9			7.6	100*	14.5	37.5
	10			9.3	28.6*	13.0	43.4
	11			8.8	25.0*	12.0	36.6
	12			10.8	100*		
	13			9.6	100*		
	14			5.6	0*		
	15			9.6	33.3*		

\*Fewer than 5 keypecks occurred.

quency of treadle presses at a stimulus value displaced from S+ in a direction away from S-. Key pecking gradients were more variable, with a peak at S+ for Subject 6, at the stimulus intermediate to S+ and S- for Subject 4, and shifted from S+ away from S- for Subject 5. Results of the second generalization test paralleled those of the first.

## DISCUSSION OF EXPERIMENT 1

### *Behavioral Contrast*

Behavioral contrast for pigeons pressing treadles was observed in Experiment 1, but not with the reliability previously observed for pigeons pecking keys (Reynolds, 1961a;

Terrace, 1966; Bloomfield, 1967). Each pigeon in Experiment 1A showed behavioral contrast when the response-reset dependency was imposed, but no substantial positive contrast occurred previous to the response-reset dependency. Since discrimination training in Experiment 1B was begun before responding had stabilized, there was no baseline from which to measure contrast.

One conclusion to be drawn from the present data is that some behavioral contrast can be obtained for pigeons pressing treadles, just as it has been observed for rats pressing levers. However, just as with rats pressing levers (see Schwartz and Gamzu, 1977), behavioral contrast is a less robust phenomenon when pigeons press treadles.

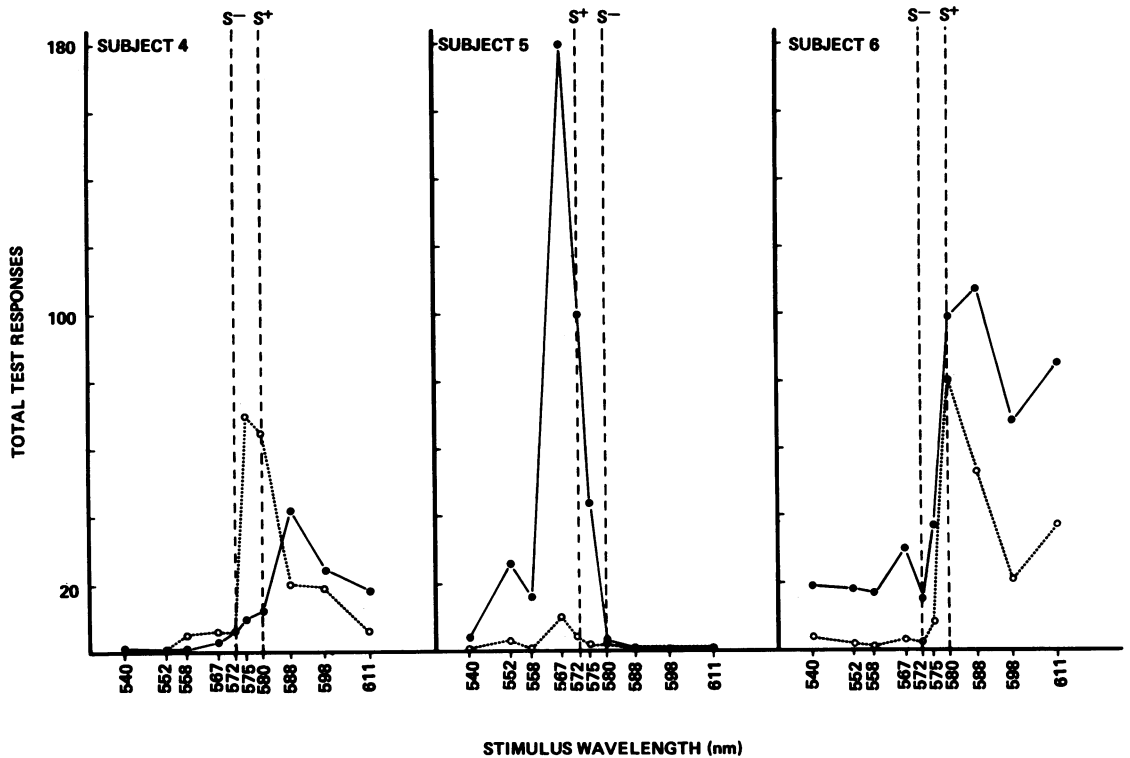


Fig. 5. Total treadle presses (closed circles) and key pecks (open circles) emitted to each stimulus during the first extinction stimulus-generalization test for each subject in Experiment 1B.

### Key-Pecking Data

In general, pecking on the stimulus key emerged primarily in S1 when the pigeons were on differential schedules and disappeared when on nondifferential schedules. These results support and extend those of Gamzu and Schwartz (1973), whose procedure differed from the present one primarily in that no treadle press was present and no response was required for food delivery. In the present experiments, there was often substantial pecking during the S2 extinction-associated stimulus early in discrimination training. Although this result is not predicted by a respondent, food-elicited characterization of the key pecks, it is consistent with findings of Gamzu and Schwartz (1973). These investigators suggest two possible explanations: (a) the extinction-associated pecking was maintained by stimulus generalization, and (b) the extinction-associated pecking was maintained by changes in the key stimulus to the one associated with food presentation. The present results suggest that the S2 pecking may be due to a poorly de-

veloped discrimination, for as discrimination training proceeded, the S2 key pecking declined considerably.

One could argue that the key pecks observed in Experiment 1A were adventitiously maintained operant key pecks. However, the results of Experiment 1B make this hypothesis highly unlikely. The key pecks were maintained during differential training, decreased to zero or near-zero rates during nondifferential training, and reappeared in the first session of the second differential training. If the pecks were adventitiously reinforced by food presentation in Phase 1, one would expect them to increase in frequency or at least remain stable in Phase 2, when more reinforcements were obtained. Likewise, if the key pecks were involved in a superstitious chain of key pecks and treadle presses, one would expect key pecks to increase during the nondifferential phase when treadle pressing occurred in both S1 and S2. Finally, the preponderance of key pecks at the beginning of each S+ interval is consistent with an autopeck interpretation (Schwartz et al., 1975).

### *Stimulus-Generalization Gradients*

The present data provide the first reliable demonstration of peak shift for pigeons pressing treadles. These data indicate that the production of peak shift by pigeons may be independent of the operant studied. Unlike behavioral contrast, the phenomenon appears to be equally robust with key pecking and treadle pressing. Unfortunately, the present demonstration of peak shift depends on the assumption that a generalization gradient after nondifferential training would peak at S+ or be flat. Such nonshifted gradients have been shown for pigeons pecking keys (Dysart, Marx, & Nelson, 1974; Kalish & Guttman, 1957) and for rats pressing levers (Weiss & Schindler, 1978) but not for pigeons pressing treadles.

Only one of six subjects produced a peak shift for key pecking. The possibility exists that the higher rates of treadle pressing during peak shift may have interfered with key pecking. However, this seems unlikely. During training, pecking often increased with increases in treadle pressing. In addition, treadle response rates were lower in the extinction generalization test than in much of training.

This absence of peak shift for the stimulus-directed "autopecks" was not predicted theoretically. Previous demonstrations of excitatory and inhibitory gradients for autopecks following interdimensional discrimination training (Tomie et al., 1976; Wessells, 1973) indicate that a peak shift should be obtained following intradimensional training. Both Spence's and Blough's theories of dimensional stimulus control predict peak shift after such training. Nevertheless, in the few studies exploring peak shift following classical conditioning, reliable peak shift has been obtained *only* when S+ was a higher frequency tone than S- (Hupka, Liu, & Moore, 1969; Liu, 1971; Moore, 1972). These results suggest that peak shift is not a robust phenomenon for elicited behavior.

The observed absence of peak shift for autopecks suggests that S- failed to acquire substantial inhibitory control. In contrast, Wessells (1973) found that in a discriminated autoshaping procedure the S- *does* acquire inhibitory control, as revealed by retarded autoshaping in the presence of the previous S- and by suppression of responding on a combined cues test. The inconsistency may lie in the amount of inhibitory control acquired

by S-. Gutman (1977) found that an S- acquired more inhibitory control when both operant and Pavlovian inhibition were operating in S- than when only operant inhibition was operating. The S2 stimulus in the present study should have acquired no operant inhibitory properties for autopecks, as autopecks do not show operant properties. Furthermore, there was no key peck rate reduction in S2 during discrimination training, a requisite condition for the formation of operant inhibition according to Terrace (1966b, 1972). Pavlovian inhibition to the S2 stimulus should have been acquired; the S1 stimulus signaled food (CS+), and the S2 stimulus explicitly signaled no food (CS-). Since only one type of inhibition was probably present, one would expect the occurrence of peak shift to be less probable, a position recently proposed by Weiss (1978). The present data support this prediction; only one subject showed peak shift. Nevertheless, all subjects produced asymmetrical gradients with an area shift away from S-. This area shift shows that the S2 stimulus affected the shape of the gradients in a manner expected of an inhibitory stimulus; responding to stimuli on the S- side of S+ was suppressed relative to responding to stimuli on the other side of S+. It may be that Pavlovian inhibition alone is insufficient to produce the peak shift consistently, but is sufficient to skew the gradient away from S-.

### EXPERIMENT 2

Little has been published concerning peak shift and behavioral contrast when negative reinforcement maintains responding: i.e., when responding allows the animal to avoid an aversive stimulus such as electric shock. Difficulties in obtaining shock avoidance baselines for pigeons pecking keys (Hoffman & Fleshler, 1961; Rachlin & Hiline, 1967) probably account for this omission. The treadle-press procedure provides an effective means for training pigeons to avoid shock (Smith & Keller, 1970). Consequently, the methods of Experiment 1 can be adapted to a shock avoidance procedure, so that behavioral contrast and peak shift can be compared when positive and negative reinforcement maintain responding. Experiment 2 examined these phenomena when differential responding was maintained by negative reinforcement.

### *Behavioral Contrast and Aversive Control*

The few studies of behavioral contrast and aversive control of responding have produced equivocal results. De Villiers (1972) observed positive behavioral contrast in each of three rats when an equal-valued multiple free-operant avoidance (FOA) schedule was changed to an unequal-valued multiple FOA FOA schedule, in which response rate and shock frequency were higher in S1 than in S2. Wertheim (1965) found positive contrast for three rats using similar procedures. However, he only looked for contrast during the first hour after the S2 schedule change, so the contrast he observed may have been highly transient. Appel (1960) and Weiss (1975) each failed to obtain positive contrast when the S2 component of a multiple FOA FOA schedule was changed to Extinction (no shocks). Klein and Rilling (1974) and Rilling and Budnik (1975) failed to find contrast after intradimensional discrimination training (multiple FOA Extinction schedules) for pigeons pressing treadles to avoid shock. The paucity of data concerning behavioral contrast with negative reinforcement schedules makes it difficult to draw general conclusions. Nevertheless, the available data suggest that behavioral contrast is not a reliable phenomenon when negative reinforcement maintains behavior.

### *Generalization of Free-operant Avoidance*

No reports have been published demonstrating reliable peak shift after FOA training. Klein and Rilling (1974) studied generalization of FOA in pigeons following intradimensional discrimination training. They failed to obtain reliable peak shift, although a pronounced area shift occurred and one bird showed peak shift during some tests. Nevertheless, the results of this study are insufficient to conclude that peak shift rarely occurs in pigeons after FOA training, because the stimulus parameters used were unusual (i.e., 1000-Hz and 1500-Hz tones). Since stimulus parameters affect peak shift (Boneau & Honig, 1964; Dickson & Thomas, 1963), examining generalization gradients following negative reinforcement using stimulus values known to result in peak shift under positive reinforcement contingencies seems warranted.

Experiment 2 of the present study provides an investigation of peak shift and behavioral

contrast with negative reinforcement contingencies, using stimulus and response parameters that produced these phenomena with positive reinforcement contingencies in Experiment 1. The present investigation consisted of two phases: (1) multiple FOA FOA training and (2) multiple FOA Extinction training, with a generalization test administered after Phase 2. Responses on the treadle and on the stimulus key were recorded, although only responses on the treadle delayed shock. Stimulus parameters and response requirements were the same as in Experiment 1. The primary difference was the reinforcer maintaining responding: i.e., food presentation versus shock avoidance. This allowed a direct comparison of contrast and generalization gradients obtained following positive and negative reinforcement.

## METHOD

### *Subjects*

Three male White Carneaux pigeons, approximately one year old at the beginning of the experiment, served. They were maintained at 80% of their freefeeding weights. All were experimentally naive and were housed separately with free access to water and grit. Subjects had stainless steel electrodes implanted through the pubic arch and wore leather harnesses with electrical connector on the back (Azrin, 1959).

### *Apparatus*

The apparatus was the same as in Experiment 1, with the following exception. A coiled cable attached to a mercury commutator connected the shock source to the pigeon harness. The shock source was 110-V AC wall current connected in series to a 1000-ohm resistor and milliammeter. A potentiometer allowed adjustment of milliamperes of shock received by the pigeon. The duration of the shock was adjustable.

### *Procedure*

*Initial training.* Subjects 7, 8, and 9 were trained to avoid shock by pressing the treadle. On Day 1, the pigeons were trained to press the treadle; i.e., treadle pressing produced escape from trains of .45-sec 4-mA shocks administered manually. Next, each subject received FOA training in which responses postponed shocks. On Days 2 and 3 each treadle

press postponed the .45-sec 4-mA shock for 30 sec, the response-shock (RS) interval, and shocks occurred every 3 sec in the absence of treadle pressing, the shock-shock (SS) interval. On Day 4, shock intensity was increased to 8 mA for all subjects and the schedule parameters were changed to RS = 25 sec and SS = 5 sec for Subjects 8 and 9. Training continued until there was no increasing or decreasing trend in response rate for four days and the subject was avoiding 75% of scheduled RS shocks. Subjects 7, 8, and 9 received 25, 10, and 14 days, respectively, of training on this free-operant avoidance schedule. For Subject 7, a 572-nm light illuminated the stimulus key on even days and a 580-nm light illuminated the key on odd days. For Subjects 8 and 9, the 572-nm and the 580-nm lights alternated randomly within a session (beginning on session 4), but the FOA parameters operated independently of stimulus condition; i.e., the stimulus did not have any discriminative function. Throughout the nondifferential training, sessions terminated after 4 hr or 200 shocks, whichever occurred first.

*Discrimination training.* Following four days of stable performance on the FOA schedule, the schedule was changed to multiple FOA Extinction. The FOA-associated keylight was 572 nm for Subjects 7 and 9 and 580 nm for Subject 8; the extinction-associated keylight was 580 nm for Subjects 7 and 9 and 572 nm for Subject 8. Each stimulus was presented for 1 to 3 min, followed by a 1-sec blackout. After each blackout, the probability was .5 that the 572-nm light would be initiated and .5 that the 580-nm light would be initiated. Subjects received discrimination training until they met the following criteria: (a) at least 75% of responding occurred in the S1 component; (b) there was abrupt and sustained response-rate reduction on at least 75% of the S2 presentations; (c) at least one response preceded the first shock during an S1 presentation on at least 50% of the occasions; (d) 75% of RS shocks were avoided; and (e) no increasing or decreasing trend in response rate was noted in either component.

In order to improve performance so that the criteria could be met, schedule parameters were manipulated differentially for each subject. Therefore each subject's discrimination training will be described separately. Subject 7 received the simplest training: 32 sessions of

multiple FOA Extinction training, .45-sec 8-mA shocks, and equal-duration S1 and S2 components of 1 to 3 min. Subject 8 received 11 sessions of multiple FOA Extinction training, .45-sec 8-mA shocks, and 1- to 3-min S1 and S2 components. For Sessions 12 through 31 of discrimination training, the shock was lowered to 5 mA, and for Sessions 32 through 43 the S2 stimulus duration was lengthened to 15 min while S1 remained 1 to 3 min. Because S2 responding was not decreasing, a dependency was introduced whereby 10 treadle presses occurring in S2 produced S1—i.e., reinstated the FOA schedule; otherwise, S2 remained in effect for 3 min. This fixed-ratio (FR) in S2 is the converse of the response-reset in the Extinction component of the positive reinforcement schedules of Experiment 1. S1 durations continued to range from 1 to 3 min. The FR 10 dependency remained in effect for five sessions (Sessions 44 through 48) and then was reduced to FR 5 for Sessions 49 through 72. Subject 9 began discrimination training with 30 sessions of a multiple FOA Extinction schedule, .45-sec 8-mA shocks, and 1- to 3-min S1 and S2 components. Shock level was increased to 10 mA for Sessions 31 through 33, 11 mA for Sessions 34 through 36, 13 mA for Sessions 37 through 39, and 14 mA for Sessions 40 through 49.

Throughout discrimination training, sessions terminated when 200 shocks had occurred or 6 hr had elapsed. Both treadle presses and key pecks were recorded, although key pecks had no scheduled consequence.

*Extinction stimulus-generalization test.* A stimulus-generalization test was administered when discrimination criteria were met. Stimulus sequences and durations were similar to those in Experiment 1. Shock was discontinued in testing, and the complete test was administered within one session. On the testing day, a 1-hr period of regular multiple FOA Extinction training preceded the extinction test, and 15-min reacquisition periods of multiple FOA Extinction training were interspersed between test blocks whenever the subject emitted *no* responses within a block of 10 stimuli. Treadle presses and key pecks were recorded during the test.

## RESULTS

### *Training*

Training data for Experiment 2 subjects

are shown in Figure 6. Treadle-press rates in S1 (closed circles) and S2 (open circles) are shown for the criterion sessions of multiple FOA FOA training. Key-peck rates are not shown because the pigeons in this experiment did not peck the stimulus key. For each subject, treadle press rates were fairly comparable in S1 and S2 at the end of nondifferential training. When the schedule was changed to multiple FOA Extinction, Subjects 7 and 9 showed a small, transient increase in S1 treadle press rates as S2 treadle press rates decreased. Subject 8 failed to produce an S2 response-rate reduction upon initiation of the multiple FOA Extinction contingencies, but after several schedule manipulations (see Figure 6), S2 treadle pressing decreased to a low rate. S1 treadle

press rates never exceeded baseline values for Subject 8.

#### Stimulus-generalization Test

Figure 7 depicts the generalization gradients of the treadle press response for the FOA subjects. Each subject produced a peak displaced from S+ away from S-. The gradients for Subjects 7 and 9 reveal a trough at S-, and the gradient of Subject 8 shows the trough displaced from S- away from S+. No key pecks occurred during the generalization test.

#### DISCUSSION

##### Behavioral Contrast

Two of three Experiment 2 subjects produced a small, transient increase in S1 response

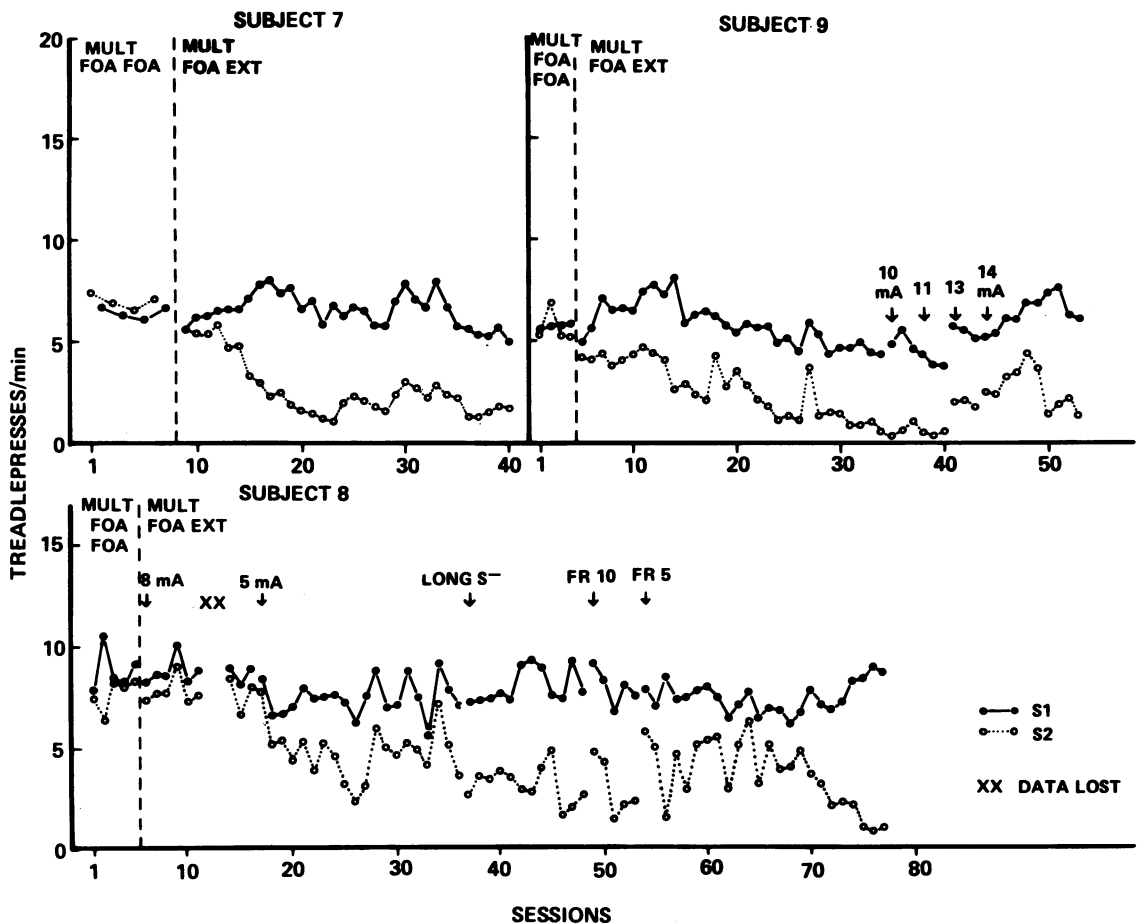


Fig. 6. Treadle-pressing rates (treadle presses/min) for each subject in Experiment 2 during nondifferential avoidance (multiple FOA FOA) training and during differential avoidance (multiple FOA Extinction) training. Closed circles represent responses in S1; open circles represent responses in S2. Schedule changes during differential training are marked by arrows and are labeled.

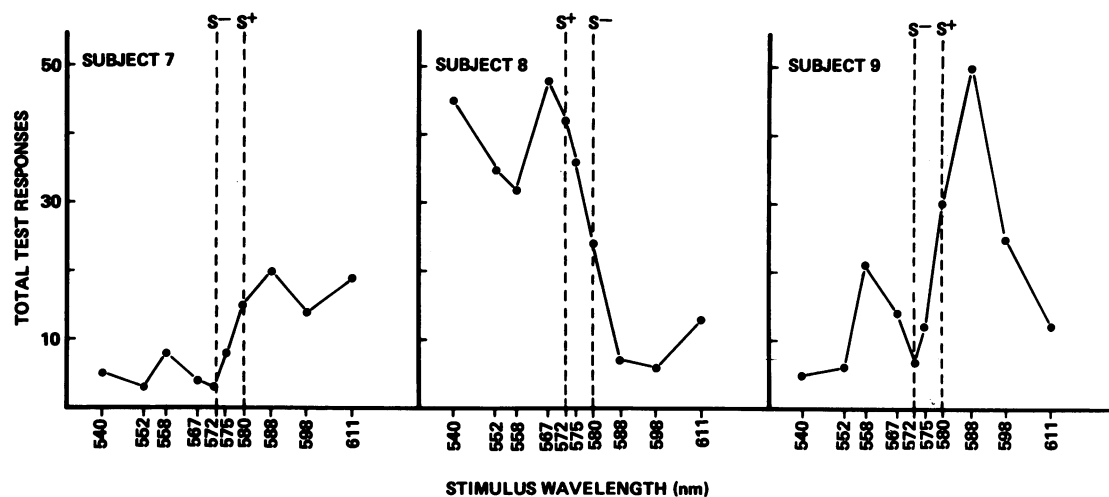


Fig. 7. Total treadle presses emitted to each stimulus during the extinction stimulus-generalization test for Experiment 2 subject.

rates as response rates decreased in S2. The S1 response rate for Subject 7 reached a value 1.4 times that of the highest baseline rate, and the S1 rate for Subject 9 reached a value 1.2 times that of the highest baseline rate. These results resemble previous findings concerning behavioral contrast when responding is maintained by negative reinforcement; positive behavioral contrast is unreliable or nonexistent (Appel, 1960; De Villiers, 1972; Wertheim, 1965).

### Peak Shift

All subjects in Experiment 2 produced peak shift. This is the first report of reliable peak shift when negative reinforcement maintains responding. The present data indicate that Klein and Rilling's (1974) failure to obtain peak shift for pigeons pressing treadles on multiple FOA Extinction schedules was not due to the response or the reinforcer used. Consequently, it could be that the stimulus values used were too widely spaced for the production of peak shift.

### Key-pecking Data

No key pecking was observed in Experiment 2 when negative reinforcement maintained treadle pressing. These results show that the stimulus key pecking observed in Experiment 1 was specifically related to food reinforcement. Although the manipulations in Experiment 1B demonstrated that the key pecking was not adventitiously maintained operant behavior, they did not show that the behavior

was exclusively related to food presentation. It may be that the key pecking was a stimulus-observing response that occurred only when S1 and S2 stimuli signaled differential reinforcement and/or response rates, but was not necessarily "elicited" by the food. The absence of key pecking in Experiment 2 shows that the pecking was reinforcement specific and therefore probably food elicited.

### CONCLUSION

The present experiments provide the first reliable demonstration of peak shift for pigeons pressing treadles and the only reliable demonstration of peak shift when negative reinforcement maintains responding. Peak shift was a robust phenomenon when pigeons pressed treadles to obtain food or to avoid shock. These results, in combination with previous demonstrations of peak shift for rats pressing levers and pigeons pecking keys, indicate that peak shift is a general by-product of operant discrimination training, occurring across organisms, responses, and reinforcers.

Peak shift was *not* found for nonreinforced "autoshaped" key pecking. Since the operant treadle presses and nonreinforced autopecks were observed under identical stimulus and food delivery parameters, the difference in shapes of the stimulus generalization gradients must be attributed to the response type. Therefore, peak shift appears to be a ubiquitous phenomenon with operant behavior but less



a reliable phenomenon with stimulus-directed nonreinforced "autoshaped" behavior.

Finally, the present data show that behavioral contrast sometimes occurs when pigeons press treadles, although the phenomenon is less robust than when pigeons peck keys. These data, in combination with results of other behavioral contrast studies, show that no single-factor explanation of behavioral contrast is adequate.

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